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Dated 1 May 2003

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1/77

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The Patent Office
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1. Your reference

PMP/LW/P/20706.GB

2. Patent application number
(The Patent Office will fill in this part)

0209183.3

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Madison Filter 981 Limited
Knowsley Road Industrial Estate
Haslingden
Lancashire
BB4 4EJ

Patents ADP number *(if you know it)*

80432 18001

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

Sumitomo Heavy Industries Ltd
2-1-1 Yato-Cho
Nishitokyo City
Tokyo 188-8585
Japan

7286453002

Japan

4. Title of the invention

Filter Elements

5. Name of your agent *(if you have one)*

WILSON GUNN M'CAW,

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

41-51 ROYAL EXCHANGE,
CROSS STREET,
MANCHESTER
M2 7BD.

Patents ADP number *(if you know it)*

7153927001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
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See note (d))

YES

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Continuation sheets of this form	
Description	10
Claim(s)	
Abstract	
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10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	X
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Wilson Gunn M'Caw Date
WILSON GUNN M'CAW 22/04/02

12. Name and daytime telephone number of person to contact in the United Kingdom

PATRICIA M. PHILLIPS
0161-827 9400

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FILTER ELEMENTS

The present invention relates to filter elements and in particular, but not exclusively, to hollow elongate porous filter elements used for gas filtration.

Waste gas from industrial processes such as municipal waste incinerators is filtered to remove contaminants such as dioxins, furans, nitrous oxides, dust, soot and other toxic and noxious substances, thereby enabling the waste gases to be more safely released into the atmosphere. Traditionally gaseous pollutants have been removed by a process of gas 'scrubbing' by injecting a reactant particulate material into the waste gas which reacts either chemically and/or physically with the gaseous pollutants to produce a particulate reaction product. The waste gas containing the reaction product is then filtered through a barrier filter such as a textile, metal or ceramic medium, with the reaction product and any solid pollutants present being retained as a dust cake on the surface of the filter. This has the disadvantage that it involves the handling and injection of a powder or slurry reactant material and the subsequent removal of the dust cake from the surface of the filter. The dust cake is usually removed by back-pulsing clean air under pressure through the filter which results in an increase in energy requirements for cleaning and for filtration. This is because the dust cake presents a pressure drop penalty as it provides a more impermeable layer to the gas flow, thereby requiring extra energy to pull clean gas through the cake and filter. Furthermore, after cleaning there is no build up of reactant material at the surface of the filter, which in use would provide a reactant bed

for the removal of pollutants, this enables pollutants to more readily pass untreated through the filter until the reactant layer can be built-up again.

In order to alleviate this later drawback a method of filtration was developed as described in EP 0 573 209 (Foseco International Limited), which operates by initially passing clean air containing particulate reactant material through a rigid, porous ceramic filter. This enables a layer of reactant material to build-up on the surface of the filter before the filtration of the waste gas commences. The clean air is then replaced by the waste gas and the reaction between the gaseous contaminants and the reactant material occurs at the surface of the filter, with a subsequent build-up of reaction product as a dust cake on the filter's surface. Additional reactant material may be added to the stream of waste gas during the continuing filtration. This process still has the disadvantage that the reactant material together with formation of the dust cake on the surface of the filter presents an impermeable layer requiring additional energy to extract cleaned gas. Also, regular cleaning is still required to periodically remove the dust cake with reduced filtration efficiency after cleaning and increased possibility of untreated gas passing through the filter.

EP 0 573 209 further describes the use of activated carbon or powdered lime as a particulate reactant material to absorb gaseous contaminants such as organic chemicals and acidic gases respectively. However, activated carbon when used in this manner is in the form of a dust, which is particularly messy to handle. Activated carbon which has been used to absorb chemical contaminants is typically regenerated by heating to a high temperature in an inert atmosphere, for example nitrogen. Therefore, when activated carbon is used as a particulate reactant medium, it is not

cost effective to also include other particulate reactants to remove additional contaminants, since other particulate material would be then mixed with the activated carbon, with the additional requirement for other separation procedures to isolate the other particulate material from the carbon.

EP 2 242 488 (Mitsubishi Jukogyo Kabushiki Kaisha) describes a ceramic filter coated with several layers of chemicals, such as slaked lime, calcium carbonate and calcium chloride which form a catalytic barrier to extract noxious gaseous chemicals such as hydrogen chloride and nitrogen oxides from waste gas. The filter is a fired ceramic matrix which requires a large amount of energy to produce. Furthermore, it is necessary to coat the filter at least three times, thereby requiring three separate application and subsequent drying stages, thus making the filter expensive to produce. Furthermore, the multi-layered structure would provide a resistance to flow, making it less effective as a filter and requiring additional energy to draw air therethrough. The filter would soon become blocked if additionally used to filter waste gas containing particulate matter. The coatings also present a high possibility of de-lamination during reverse pulse jet-cleaning to remove the accumulated dust cake. Furthermore, acidic vapour may degrade the lime coating causing de-lamination.

EP 648 535 (Corning Incorporated) describes a method of chemically cleaning gas using a high-density honeycomb ceramic filter having particulate reactant material embedded in its pores. The ceramic framework is formed by the extrusion of a honeycomb ceramic material to provide a high strength porous material. The process

requires high temperature firing at 1350°C to 1450°C in order to effect fusion of the ceramic particles, followed by a separate impregnation step to insert the reactant material. The manufacturing process is therefore time consuming and requires a large amount of energy. It is described in EP 648 535 that the maximum open porosity, that is the porosity of the honeycomb filter before the reactant material is inserted, is 55%. (This value represents the proportion of the substrate volume which is not solid). The porosity of the structure will therefore be decreased upon insertion of the reactant material into the open part of its structure, leading to a decrease in the filtration characteristics rendering the filter unable to remove both chemical and particulate contaminants at the same time. The high density and thereby low porosity of such a structure only allowing the performance of one function, either absorbing gases or removing particulates.

It is an object of the present invention to provide a filter element which overcomes or alleviates the above described drawbacks.

In accordance with one aspect of the present invention there is provided a filter element comprising a composite homogenous structure of inorganic fibres and reactant. The reactant is a substance which reacts physically, for example by adsorbing or absorbing the pollutants, or which reacts chemically to produce innocuous gaseous molecules or a particulate reaction product. The presence of reactant within the body of the filter has the advantage that the reactant is fixed into position throughout the filter body and consequently removal of the reactant and spent reactant from the surface of the filter is not required giving continuity of protection and improved efficiency of filtration, since the reactant is not accumulated on the

surface blinding the filter. Also, since the reactant and spent reactant do not accumulate on the surface, it is possible to add other particulate reactants to the waste gas upstream of the filter to specifically target other pollutants, thereby increasing the number of pollutants which can be removed. The spent other particulate reactants being removed from the surface of the filter in a known manner, for example back-pulsing of air jets. Also, the even distribution of reactant throughout the filter means that the waste gas must pass many more reactant particles upon its passage through the filter when compared to the reactant being merely provided on the filters surface, thereby increasing the probability of reaction and removal of the pollutant. The reactant material also acts as a filler enabling control of the porosity of the finished filter by selection of the quantity of the reactant added. Also, the type of reactant can be selected to best serve a particular filtration application.

In a preferred embodiment the filter element is in the form of a vacuum-formed structure. It has been found that vacuum forming of the present filter provides a filter having a considerable increase in porosity, typically 70 to 80% porous due to the low density distribution of the fibres and reactant. Compare this to a maximum of 55% for fired filters such as that described in EP 648 535. The structure of the present invention has the advantage that the filter additionally provide a more efficient dust filter since it remains porous during dust cake build-up. This enables dual function of the filter in that it can eliminate particulate pollutants as well as gaseous pollutants, and requires less frequent cleaning by reverse pulse-jet with consequential decrease in down-time and energy consumption. Also, it has been found that this lower density filter produces lower density dust cake, which is much easier to remove

during the cleaning cycle. The less dense filter is also less heavy making it easier to handle. The increase in porosity enabling the clean gas to be more easily drawn therethrough, further decreasing energy requirements. Also, as the filtration cycle proceeds, the low-density, highly porous filter will 'blind' at a much slower rate, ensuring energy consumption remains low.

The inorganic fibres may be selected from the list ceramic fibres, crystalline mineral fibres, amorphous mineral fibres, mineral wool, glass fibres and other fibres with refractory properties. Ceramic fibres may include those comprising alumina, alumino-silicate, calcium silicate or other silicates.

The reactant may be activated carbon and/or catalyst.

The catalyst may comprise at least one precious metal which may be further supported on alumina particles. Preferably the precious metal comprises 0.1 – 1% of the mass of the reactant. More preferably the precious metal is at least one of the group platinum, palladium, ruthenium, aluminium, titanium and vanadium.

The activated carbon may be in the form of a powder and/or fibre. Providing the activated carbon powder within the body of the filter eliminates the need to inject it into the waste gas stream, thereby eliminating the problems associated with handling the activated carbon in use. If it becomes necessary to reactivate the carbon, this can be achieved simply by heating the filter element in a nitrogen atmosphere to, for example at least 400^{0}C. This would not present a problem to the ceramic structure since it is capable of withstanding temperatures of at least 800^{0}C, thus providing a cost effective means of recycling the carbon.

The structure may additionally comprise a binder system. This has the advantage of providing structural integrity to the ceramic fibre/reactant mass. The binder system may comprise colloidal silica or colloidal alumina and at least one of cationically modified starch or a flocculant. The flocculant may be selected from the list poly acrylamide, anionic or cationic organics or inorganic complexes.

In a preferred embodiment the filter element is a hollow, candle shaped filter element, closed at one end. This type of filter element finds application in many existing filtration apparatus. The reactant may comprise 35 to 40% (by mass) of a 1 metre filter element weighing 750 to 800g.

In accordance with a second aspect of the present invention there is provided a method of manufacture of a filter element comprising the steps of dispersing ceramic fibres and reactant in water, adding a binder system, and mixing, vacuum forming to provide a filter element of the desired shape and leaving the filter element to dry. This method is relatively cheap since high temperature firing is not required, the vacuum forming may occur at room temperature and subsequent heating at a temperature to dry the formed element. Also, vacuum forming provides a filter of comparatively low density and consequently high porosity.

The reactant may comprise activated carbon, the filter element thus produced comprises activated carbon in an easily handled form, in that it is fixed within the body of the filter, and thus eliminates the problems associated with adding activated carbon in particulate form to a waste gas stream and also the consequential removal of spent carbon from the surface of the filter. The reactant may additionally comprise a catalyst.

In accordance with a third aspect of the present invention there is provided an apparatus for removing contaminants from waste gas, comprising at least one filter element formed from a homogenous structure of inorganic fibres and activated carbon, means to supply the waste gas to be filtered to the at least one filter element, and means to supply hot nitrogen gas to the at least one filter element. This has the advantage that the carbon in filter(s) can be reactivated in situ without having to remove the filter elements. In a preferred embodiment the apparatus further comprises means to heat the gas to at least 400°C.

By way of example only specific embodiments of the invention will now be described.

In a first embodiment, 15kg of alumino-silicate ceramic fibre and 2kg activated carbon powder are dispersed in 1000kg of water. 3.7kg of colloidal silica (35% solids) is then added and the ingredients mixed to ensure adequate dispersion. 0.8kg of cationic modified starch is then added as a 4% solution, after being dissolved previously in 20kg of water. Candle-shaped filter elements, closed at one end, are formed by vacuum-forming the slurry to provide a filter element 1m long with an internal diameter of 35mm. The wet candles are subsequently dried at 110°C for eight hours to provide a finished filter element.

In a second embodiment, 10kg of alumino-silicate ceramic fibre and 7.5kg activated carbon powder are dispersed in 1000kg of water. 6.81 kg of colloidal silica (35% solids) is added and the resultant solution mixed. 0.8kg of cationically-modified starch is then added as a 4% solution (dissolved in 20kg of water) and the resultant solution mixed at slow speed for a couple of minutes. 0.01kg of

the outer surface of the filter element, as well as a superior cake release due to decreased cake density, ensuring it is easily dislodged by reverse pulse-jet cleaning.

Also, the present filter element can effectively remove gaseous contaminants from a gas stream while simultaneously retaining enough permeability to function as an exceptional filter of particulates, a function not demonstrated by previously known filters. This is possible because the removal of gaseous contaminants does not impinge on the removal of particulates, and visa versa and in that the reactant material and dust cake are easily isolated for further regeneration or processing. The dust cake may be removed by conventional means such as the back pulse of a high pressure air jet. When the reactive material is activated carbon, the carbon may be reactivated by heating the filter element in a high temperature nitrogen atmosphere. In a further embodiment the filtration filter element(s) is utilised in a filtration apparatus for the treatment of waste gas, the filtration apparatus comprising means to supply high temperature nitrogen to the filter element(s) to regenerate the carbon within the filters.

Although a candle-shaped filter of a specific size has been described, it is to be understood that other sizes of candle shaped filters could be produced or alternative shaped filters could be vacuum formed to provide a composite filter structure of ceramic fibres and reactant material. Although ceramic fibres have been described, the filter element could be constructed from other refractory inorganic fibres or a combination thereof.